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Gary M. Hartman Date: February 19, 2007

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.	:	10/707,999	Confirmation No. **1998**
Applicant	:	Srinivasan Chandrasekar et al.	
Filed:	:	January 30, 2004	
TC/Art Unit:	:	1742	
Examiner	:	Ngoclan T. Mai	
Docket No.	:	A4-1719	
Customer No.	:	27127	

Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

DECLARATION UNDER 37 CFR §1.132

We, Srinivasan Chandrasekar, Walter D. Compton, Thomas N. Farris, and Kevin P. Trumble, depose and say:

(1) We are joint inventors of the subject matter covered by the claims pending in the above-identified patent application ("Application").

(2) Our curricula vitae are attached hereto for the purpose of evidencing our expertise in the art pertaining to the invention disclosed in the Application. During our respective employments with Purdue University, we have been engaged in various research activities, including the phenomenon and properties of nanocrystalline materials, processes for producing nanocrystalline materials, and processes for producing products from nanocrystalline materials. Collectively, we have authored in excess of 350 journal and conference publications, with more than two-thirds of these pertaining to materials processing, mechanical behavior and properties of advanced materials, etc., and with about forty of the papers related to nanostructured materials. Collectively, we have also advised more than one hundred graduate theses in research topics pertaining to materials, materials processing, and manufacturing.

(3) We are aware that claims 1, 2, 4, 6, 13, 14, and 16 of the Application are rejected as claiming subject matter obvious in light of U.S. Patent No. 5,939,146 to Lavernia.

(4) Rejected claim 1 is reproduced below for the convenience of this discussion.

> Claim 1: A product consisting essentially of polycrystalline chips and optionally a matrix in which the chips are dispersed, the polycrystalline chips having nanocrystalline microstructures and being formed of a material chosen from the group consisting of metals, metal alloys, intermetallic materials, and ceramic materials, the matrix if present being formed of a material chosen from the group consisting of metal, metal alloy, intermetallic materials, polymeric materials, and ceramic materials;
>
> wherein the chips are produced by a machining operation so as to be in the form of ribbons, wires, filaments, and/or platelets;
>
> wherein if the product consists essentially of the chips, the chips are held together by consolidation and the product is a monolithic material consisting essentially of a nanocrystalline microstructure; and
>
> wherein if the product consists essentially of the chips dispersed in the matrix material, the product is a composite material.

(5) The following is our discussion of Lavernia and the differences between a product formed by Lavernia's process and a product formed by machining as required for our claimed invention.

From our reading of Lavernia, we understand that Lavernia describes a method in which material particulate is ball milled to produce

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agglomerates (agglomerated particles) having nanocrystalline internal structure. The agglomerates are then consolidated by thermal spray processes to form an "object characterized at least in part by a nanocrystalline microscopic structure" (Claim 1 of Lavernia), with the result that "thermally sprayed coatings of high quality nanocrystalline material are achieved with the retention of all the material properties and benefits of nanocrystalline material" (Lavernia at column 3, lines 28-30). Thermal spray processes typically employ particles larger than about 10 μm because smaller particles tend to be, as Lavernia describes, "blown out of the spray to the peripheries with the result that the particles would not be heated or well deposited." Lavernia uses particles (agglomerates) in a "typical" size range of 20-100 μm for this reason (Lavernia at column 2, line 64-column 3, line 22).

Difference in Structure of Ball Milled Agglomerates and Chips

For purposes of discussion, Lavernia's nanocrystalline agglomerates are particles that find analogy to the nanocrystalline "chips" described in our claim 1. Whereas Lavernia's consolidation step relies on the nanocrystalline agglomerates having a restricted size range, nanocrystalline chips used to

form our product are not restricted to a particular size or particular consolidation process.

Although Lavemia's agglomerates and our chips contain a nanocrystalline internal structure, there are characteristic differences in these structures resulting from the different deformation paths that produce them. In Lavernia's ball milling processes, starting particles are repeatedly flattened, bonded, fracture, and rebonded between the impacting surfaces of larger ball milling media (e.g., balls). A distinct grain structure is usually difficult to resolve in TEM and grain size values are often reported on the basis of x-ray line broadening correlations. The deformation is analogous to hammering, which results in axisymmetric compression (strain), in which significant strain occurs in all three dimensions (particles are compressed in one direction and extended in the two transverse directions), yielding an associated crystallographic texture or preferred orientation of the grains within the agglomerates that is characteristic of deformation by axisymmetric strain. In contrast, the type of deformation that occurs in chip formation by machining

(cutting) is fundamentally different. It is closest to plane-strain deformation.[1] That is, strain occurs predominantly in two of three dimensions.

Differences Resulting from Consolidation

As detailed below, thermal spray processes heat the particles to a molten or partially molten state and propel them against a substrate surface where the individual equiaxed particles flatten or "splat" to form pancake-shaped particles and build up a deposit (consolidate). This process results in the characteristic ""lamellar" structure of thermal sprayed coatings. Thus, the starting morphology or shape of the particles is completely transformed by the consolidation process. It is highly unlikely that an interior nanocrystalline starting structure in the particles also would not be completely destroyed or substantially altered in thermal spray processes.

On the basis of the above, we believe that structures of products

[1] "When the tool cutting edge is perpendicular to the cutting velocity and the width of cut is small compared to the cutting edge length and t_o, a state of plane strain deformation prevails, which is believed to be a preferred configuration for experimental and theoretical investigations of machining." Paragraph [0022] of the Application.

formed with our nanocrystalline chips physically differ from structures formed by thermal spraying Lavernia's nanocrystalline agglomerates.

Lavernia describes a method that can use all the main variants of thermal spray processing (air plasma spray, arc spraying, detonation gun spray, high velocity oxy-fuel spray, vacuum plasma spray, controlled atmosphere spray, and flame spray). All thermal spray processes, as the name implies, entail heating solid particles close to or above their melting point in a hot gas jet (torch) and propelling the particles against a substrate. At page 361 of *The Metals Handbook*, Ninth Edition, Volume 5, American Society for Metals (1982), thermal spray is described as

> the material (powder) is metered...into a compressed air or gas stream which suspends and delivers the material to the flame where it is heated to a molten or semi-molten state and propelled to the workpiece, where a bond is produced upon impact.

Another leading authority, R. C. Tucker, Jr., Advanced Thermal Spray Deposition Techniques, in *Handbook of Deposition Technologies for Films and Coatings*, Second Edition, Noyes, Park Ridge New Jersey (1994), pp 591-642, describes the plasma, detonation gun and high velocity oxy-fuel spray

processes as,

> processes in which powder is heated to near or above its melting point and accelerated...and on impact forms a coating consisting of many layers of overlapping thin lamellar particles or splats. Almost any material that can be melted without decomposition can be used to form the coating.

This last sentence again implies that at least some degree of melting is an integral feature of the processes. Indeed, torch temperatures of thousands to tens of thousands of degrees centigrade are cited in this and many other sources. Therefore, it is highly unlikely, if not impossible, for the nanocrystalline structures of Lavernia's starting agglomerates to be retained during exposure to such extreme heating. Even if the particles do not melt, coarsening of nanocrystalline structures generally proceeds rapidly at temperatures above even $0.5T_M$ (T_M = melting temperature in Kelvin).

The only justification for why the nanocrystalline structure of Lavernia's agglomerates would not coarsen during the extreme heating of the thermal spray process is found in Lavernia at column 2, lines 5-12, which reads as follows:

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> What is perhaps most unusual about nanocrystalline materials is the fact that, despite being classified as nonequilibrium materials, recent work shows that their grain size may, in some cases, remain metastable during exposure to elevated temperatures. Although this phenomenon is not clearly understood, it has been suggested that the unusual resistance of nanocrystals to coarsening may be due to their narrow size distribution.

Lavernia does not provide any support for the allegations concerning the "recent work" and what "has been suggested" regarding nanocrystalline materials being metastable and resistant to coarsening. On the other hand, there is evidence in the literature that, in some cases, due to rapid quenching of the particles as they deposit on the substrate, metastable phases may form, e.g., transition aluminas, as cited in Tucker at page 615. It is also well known that liquid droplets cooled sufficiently rapidly can crystallize in what was originally called a "microcrystalline" structure, but today would be considered "nanocrystalline." By reference, thermal spray processes might result in such a nanocrystalline structure, but the origin of any such structure would be in the rapid cooling of liquid droplets and thus have nothing whatever to do with the nanocrystalline structure of Lavernia's agglomerates, since they would have to first undergo melting that would completely destroy their nanocrystalline structure. Lavernia's conjecture of thermal stability in his nanocrystalline

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agglomerates clearly shows that the proposed nanocrystalline structure in a thermal sprayed coating produced with the agglomerates was envisioned to be that retained from the agglomerates, and not produced by transformation during thermal spray consolidation. However, Lavernia does not provide any evidence that nanocrystalline microstructures were present in the coatings produced by Lavernia's process (column 11, line 41-column 12, line 5).

Nanocrystalline structure aside, there are other levels of structure that distinguish thermal spray microstructures. The initial particles are flattened into pancake-shaped splats having a thickness on the order of about 1 μm and aspect ratio of about 20 to 40, which form a characteristic wavy lamellar structure. Because the lamellae are formed directly from the starting powder particles, their thickness is directly proportional to the starting particle size (nominally the volume of a lamella equals the volume of the particle from which it formed). The deposit has a strong texture due to the anisometric shape of the lamellae. Only if we consolidated our chips by thermal spray would our product exhibit this particular structure.

Lavernia does not describe a specific form for the thermal sprayed

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deposit produced with his process. However, thermal spray is typically limited to producing coatings. Thermal spray processes can be performed for extended periods of time to build up bulk forms, but with the detriment that the deposited layer experiences a longer duration of heating. Everything else being constant, the thicker the deposit, the greater tendency there will be for thermal coarsening of the deposit's microstructure through grain growth, resulting in loss of the nanocrystalline microstructure.

In view of the above, we believe

(A) Lavernia's agglomerates are characterized by <u>axisymmetric</u> strain deformation, whereas our chips are distinguishable as a result of being produced by machining processes that primarily induce <u>plane</u> strain deformation.

(B) Lavernia's thermal spray process inherently causes at least partial <u>melting</u> of the agglomerates such that at least a portion of their nanocrystalline microstructure is destroyed, whereas our chips do not undergo melting and therefore their nanocrystalline

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microstructures are not destroyed.

(C) Lavernia's thermal spray process is generally limited to coatings and if used to produce a bulk product will lead to prolonged heating and grain growth, with the result that Lavernia's thermal sprayed coating/product would not be "a monolithic material consisting essentially of a nanocrystalline microstructure" as required by our claim 1

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Srinivasan Chandrasekar

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

W. Dale Compton

Walter D. Compton

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I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Thomas N. Farris

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Kevin P. Trumble

Kevin P. Trumble

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S. Chandrasekar

Present Position
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Professional Preparation

Indian Institute of Technology, Madras, India	Mechanical Engineering	B. Tech (1981)
Arizona State University	Engineering Science	M.S. (1983)
Arizona State University	Mechanical Engineering	Ph.D. (1985)

Appointments
- Professor, School of Industrial Engineering, Purdue University, 1994; Professor of Materials Engineering (Adjunct from August 1996); Associate Professor, 1990-1994; Assistant Professor, 1986-1990.
- Visiting Scientist with the Fracture Group, Physics and Chemistry of Solids, Cavendish Laboratory, University of Cambridge, U.K., June 1989-Sept. 1989, July 1992-Jan. 1993, May 1994-Sept. 1994, June 1995-August 1995.
- Visiting Scientist in Physical Sciences, IBM Almaden Research Center, San Jose, CA, May 1987-Sept. 1987, May Sept. 1988.
- Post-doctoral Fellow in Mechanical Engineering, Arizona State University, Tempe, AZ, January 1986-July 1986.

Research and Teaching Interests
Manufacturing Processes, Materials Processing, Structural Materials, and Tribology.

Awards NSF Presidential Young Investigator Award (1990), ASME Burt L. Newkirk Award in Tribology (1994), Visiting Associateship, Darwin College, Cambridge (1992-1997), Purdue University Distinguished Faculty Scholar (1999).

Select Publications (from 80+ Journal articles) and Patents
1. Brown, T. L., Swaminathan, S., Chandrasekar, S., Compton, W. D., King, A. H. and Trumble, K. P., "Low-Cost Manufacturing Process for Nanostructured Metals and Alloys," *Journal of Materials Research*, Vol. 17-10, 2002, pp. 2484-2488 (This paper was the subject of commentaries in magazines such as *Science News, MRS Bulletin, ASM International, Materials Today* and *Materials World*).
2. M. Ravi Shankar, A. H. King and S. Chandrasekar, 2005, "Dislocation-Indenter Interactions in Nanoindentation," *Journal of Applied Physics*, Vol. **98**, 023502.
3. Shankar, M.R., Chandrasekar, S., King, A.H., and Compton, W. D., 2005, Microstructure and stability of nanocrystalline aluminum 6061 created by large strain machining," *Acta Mater.*, Vol. 53, pp 4781-93.
4. M.R. Shankar, B.C. Rao, S. Lee, S. Chandrasekar, A.H. King and W.D. Compton, 2006, "Severe plastic deformation of titanium at near-ambient temperature." *Acta Mater.* Vol. 56, 3691-3700
5. Hebbar, R. R., Ramabhadran, R. and Chandrasekar, S., "Hybrid Servomechanism for Micro-Electro Discharge Machining," U.S. Patent No. 6,385,500, awarded May 7, 2002, joint with Cummins Engine Company.
6. Chandrasekar, S., Compton, W. D., Farris, T. N. and Trumble, K. P., "Method of Forming Nanocrystalline Structures and Product Formed Thereof," U.S. Patent No. 6,706,324, awarded March 16, 2004. Licensed to NanoDynamics.

Six patent applications are currently pending before the US Patent office.

Collaborators
H. T. Y. Yang (UC Santa Barbara), M. M. Chaudhri and J. E. Field (University of Cambridge, UK), G. Benavides (Sandia National Labs), Andrew Sherman (Ford), K. P. Trumble (Purdue), W. D. Compton (Purdue), A. H. King (Purdue), T. N. Farris (Purdue), Pin Yang (Sandia) and D. Ray Johnson (DOE/Oak Ridge).

Dr. Chandrasekar currently advises or co-advises 6 graduate students, a research engineer and two post-doctoral scholars.

W. DALE COMPTON

Education

Wabash College	B.A.	Physics 1949
University of Oklahoma	M.S.	Physics 1951
University of Illinois	Ph.D.	Physics 1955

Employment

Purdue University, West Lafayette, IN	
Lillian M. Gilbreth Distinguished Professor of Industrial Engineering	1988-2004
Lillian M. Gilbreth Distinguished Professor Emeritus of Industrial Engineering	2004-
National Academy of Engineering, Washington, DC	
Senior Fellow	1986-88
Ford Motor Company, Dearborn, MI	
Director of Chemical and Physical Sciences Laboratory	1970-73
Vice President Research	1973-86
University of Illinois, Urbana-Champaign, IL	
Professor of Physics	1961-70
U. S. Naval Research Laboratory, Washington, DC	
Research Physicist	1955-61

Teaching and Research Interest

Materials, Manufacturing, Solid State Physics, Management of Technology.

Honors

Fellow--American Physical Society	1960
Fellow--American Association for the Advancement of Science	1975
Doctorate of Engineering--Michigan Technological University	1976
Fellow--Engineering Society of Detroit	1978
Thurston Lectureship--American Soc. of Mechanical Engineers	1979
Member--National Academy of Engineering	1981
Fellow--Society of Automotive Engineers	1984
M. Eugene Merchant Gold Medal, American Society of Mechanical Engineers	1999

Current Activities - Committees, Boards, and Consulting

Purdue University	
Steven C. Beering Scholarship and Fellowship Advisory Committee	
Advisory Committee for the Center for International Business Education	
Awards Committee--Industrial Engineering--Chairman	
National Academy of Engineering	
Home Secretary	2000-
Council Member	2000-
National Research Council	
Commission on Engineering and Technical Systems--Chairman	1997-2000
Governing Board	2000-
Consultant to a number of industrial organizations	

Select Publications Related to Nanostructured Materials

1. Ackroyd, B., Akcan, S., Krishnamurthy, K. Madhavan, V., Chandrasekar, S. Compton, W. D. and Farris, T. N., 2001, "Exploration of Contact conditions in Machining," *Proc. Inst. Mech. Engrs.*, London, Series B, Vol. 215, pp. 1-15.

2. Chhabra, P. N., Ackroyd, B., Compton, W. D. and Chandrasekar, S., 2002, "Low-Frequency Modulation-Assisted Drilling using Linear Drives," *Proc. Inst. Mech. Engrs. (U.K.) Part B: J. Engg. Manuf.*, Vol. 216, pp. 321-330.

3. Brown, T. L., Swaminathan, S., Chandrasekar, S., Compton, W. D., King, A. H. and Trumble, K. P., "Low-Cost Manufacturing Process for Nanostructured Metals and Alloys," *Journal of Materials Research*, Vol. 17-10, 2002, pp. 2484-2488.

4. Brown, T. L., Swaminathan, S., Rao, B. C., Kezar, R. F., Chandrasekar, S., Compton, W. D., Trumble, K. P. and King, A. H., "Machining as a Method for Studying Effects of Very Large Strain Deformation," in *Ultrafine Grained Materials III*, Y. T. Zhu et.al. (eds.), The Minerals, Metals and Materials Society (TMS), 2004, pp. 167-172.

5. Shankar, M.R., Chandrasekar, S., King, A.H., and Compton, W. D., 2005, Microstructure and stability of nanocrystalline aluminum 6061 created by large strain machining," Acta Mat., Vol. 53, pp 4781-93.

Other Significant Publications

1. Schulman, J. H. and Compton, W. D., 1962, Color Centers in Solids, Macmillan, NY.

2. Compton, W. D., 1997, Engineering Management: Creating and Managing World-Class Operations, Prentice Hall.

3. Compton, W.D., "Encouraging Graduate Study in Engineering," 1995, *Journal of Engineering Education*, Vol. 84,No. 3, pp. 249.

4. Toews, H. G., Compton, W. D. and Chandrasekar, S., 1997, "A Study of the Influence of Superimposed Low Frequency Modulation on the Drilling Process," *Precision Engineering*, Vol. 22, pp. 1-9.

5. Allenby, B. and Compton, W. D. (eds.), 2000, Green-Tech Knowledge: Information and Knowledge Systems for Environmental Performance, National Academy Press.

Patent Related to the Research

1. Chandrasekar, S., Compton, W. D., Farris, T. N. and Trumble, K. P., "Method of Forming Nanocrystalline Structures and Product Formed Thereof," U.S. Patent No. 6,706,324, awarded March 16, 2004.

Students

Professor Compton currently advises or co-advises 4 Ph.D. and 2 M.S. students.

Biographical Sketch

Thomas N. Farris
School of Aeronautics and Astronautics
Purdue University

Thomas N. Farris is Professor and Head of the Purdue University School of Aeronautics and Astronautics. He received a BSME in 1982 from Rice University and a Ph.D. in Applied Mechanics at Northwestern University in 1986 at which time he joined Purdue University. He was appointed Head of the School of Aeronautics and Astronautics on July 1, 1998 where he administers undergraduate and graduate education and research programs. The School consists of 29 faculty who teach approximately 400 undergraduate and 200 graduate students and perform $7 million in externally funded research annually. He also has active teaching and research interests in aerospace structures with a focus in tribology, manufacturing processes and fatigue and fracture. He has supervised more than 45 M.S. and Ph.D. theses, authored or co-authored more than 100 archival publications as well as more than 100 papers and presentations at conferences, and has served as principal investigator for more than $5 million in externally sponsored research. Research in fretting fatigue led to computer software now used throughout the aircraft engine industry to assess the effect of attachment fatigue on high cycle fatigue of gas turbine engines. He has been acknowledged for research by an NSF Presidential Young Investigator Award, a Japan Society for the Promotion of Science Fellowship, the ASME/Boeing Structures and Materials Award for outstanding paper of 1998 SDM, the *Journal of Strain Analysis* P E Publishing Award in 2002, and the ASME's Burt L. Newkirk Award.

Dr. Farris has held various offices in professional societies such as the American Institute of Aeronautics and Astronautics of which he is an Associate Fellow and the American Society of Mechanical Engineers of which he is a Fellow. These include General Chair of the 41st Structures, Structural Dynamics and Materials Conference, Associate Editor of the AIAA *Journal of Aircraft,* Associate Editor of the ASME *Journal of Tribology* and member of the editorial board of *Journal of Strain Analysis.* He is a member of the Materials Technical Committee of the AIAA, the Executive Committee of the Applied Mechanics Division of the ASME, and consultant to the Army Science Board.. He was recently a member of an NRC Committee that authored *Small Business Innovation Research to Support Aging Aircraft: Priority Technical Areas and Process Improvements,* National Academy Press, 2001.

Kevin P. Trumble

Present Position

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Professional Preparation

University of Michigan	Materials and Metallurgical Engineering	B.S.E. (1985)
University of Michigan	Metallurgical Engineering	M.S.E. (1985)
University of California, Santa Barbara	Materials	Ph.D. (1990)
Max-Planck-Institüt für Metallforschung	Materials	Postdoc (1990-91)

Appointments

Purdue University, School of Materials Engineering (Prof. 2000-; Assoc. 1996-2000; Assist. 1991-1996)
University of Queensland, Brisbane, Australia, Visiting Scholar, 1/99 - 6/99
General Motors Research Laboratories, Warren, MI, Ceramist, 2/86 - 8/86.
Howmet Corporation, Whitehall, MI, Metallurgist, 5/83 - 8/83

Most relevant publications (from over 60)

1. T. L. Brown, S. Swaminathan, S. Chandrasekar, W. D. Compton, A. H. King, and K. P. Trumble, "Low-cost manufacturing process for nanostructured metals and alloys, *Journal of Materials Research*, **17**[10], 2484-2488 (2002).
2. S. Swaminathan, T. L. Brown, M. R. Shankar, B. C. Rao, K. P. Trumble, W. D. Compton, and S. Chandrasekar, "Large Scale Manufacturing of Ultrafine Grained Metals by Machining," in: Ultrafine Grained Materials III, TMS, March 2004.
3. T. L. Brown, S. Swaminathan, B. C. Rao, R. Kezar, S. Chandrasekar, W. D. Compton, and K. P. Trumble, "Machining as a Method for Studying Effects of Very Large Strain Deformation," in: Ultrafine Grained Materials III, TMS, March 2004.
4. S. Swaminathan, S. Chandrasekar, W. D. Compton, K. P. Trumble, and A. H. King, "Microstructure Refinement in Single-Phase Copper Solid Solutions by Machining," Materials Research Society Symposium Series, Vol. 821, in press.
5. S. Swaminathan, C. Swanson, T. L. Brown, R. F. Kezar, S. Chandrasekar, W. D. Compton, and K. P. Trumble, "Microstructure Refinement in Steels by Machining," Materials Research Society Symposium Series, Vol. 821, in press.

Other significant publications

1. J. L. Hilden and K. P. Trumble, "Numerical Analysis of Capillarity in Packed Spheres: Planar Hexagonal-Packed Spheres," *J. Colloid and Interface Science* **267**, 463-474 (2003).
2. F. Zhang, K.P. Trumble, and K. J. Bowman, "Functionally Graded Boron Carbide-Aluminum Composites," *Materials Science Forum,* **423-425**, 73-76 (2003).
3. R. J. Moon, K. Bowman, K. Trumble, and J. Roedel, "Fracture Resistance Curve Behavior of Multilayer Alumina-Zirconia Composites Produced by Centrifugation," *Acta Materialia*, **49**[7], 995-1003 (2001).
4. K. P. Trumble, "Spontaneous Infiltration of Non-Cylindrical Porosity: Closed-Packed Spheres," *Acta Materialia* **46**, 2363-2367 (1998).
5. F. R. Cichocki, Jr., K. P. Trumble and J. Roedel, "Tailoring Porosity Gradients via Colloidal Infiltration of Compression Molded Sponges," *Journal of the American Ceramic Society* **81**, 1661-1664 (1998).

Synergistic Activities

- Chair of undergraduate program in Materials Science and Engineering (MSE) at Purdue 1994-2004; implemented new general materials processing curriculum.

- Developed microstructure-based materials processing curriculum with support from NSF-DMR starting in 1993; five new courses including two undergraduate core courses and three graduate electives, most taught regularly on TV through Purdue Continuing Engineering Education.
- Writing an introductory MSE textbook based on applications approach. Was elected to chair third Gordon Conference on Materials Education.
- Recruiting women and underrepresented minorities to Purdue since 1992, including Minority Introduction to Engineering (MITE), MARC/AIM summer research program, and Women in Engineering Career Day.
- Executive committee, Ceramic Education Council of the American Ceramics Society (1995-1999)

Collaborators and Co-Editors

Purdue University: Keith Bowman, Srinivasan Chandrasekar, W. Dale Compton, Alex King, Elliott Slamovich, C-T. Sun; Other: Ivar Reimanis, Colorado School of Mines; Jürgen Rödel, Technical University of Darmstadt; Sanjay Sampath, State University of New York, Stony Brook.

Graduate and Postdoctoral Advisors

J. Wayne Jones, Department of Materials Science and Engineering, University of Michigan
Anthony G. Evans, Department of Materials, University of California, Santa Barbara
Manfred Rühle, Director, Max-Planck-Institüt für Metallforschung, Stuttgart, Germany

Thesis Advisor and Postgraduate-Scholar Sponsor (6 current; 27 total)

Greg A. Steinlage (PhD), GE Medical Systems
Eduardo J. Gonzalez (MS), US Secret Service
Kirk A. Rogers (MS, PhD), GE Medical Systems
Priyavardhan K. Sinha (MS), Spang and Co.
John E. Barnes (MS), Vericor
Nicholas W. Medendorp, Jr. (MS) Intel
Eric P. Bieberich (MS), Denso
Robert Moon (MS, PhD), Univesity of New South Wales, Australia
Frank R. Cichocki, Jr. (MS, PhD), Johnson and Johnson
Tim Hayes (MS) IBM
Erik Drewry (MS) Cummins
Jon Hilden (MS, PhD), Bristol-Meyer Squibb
Carl Riedel (MS), Powder Metallurgy
Erica Cattanach (MS), Federal Mogul
Will Blanton (MS, PhD), Intel
Nandini Sundaram (MS), Applied Materials
Dave Heemstra (MS), Samsung
Zhiyuan Fang (MS), Norvellus
Roland Bruyns (MS), Kodak
Lindsay Martin (MS), Johnson and Johnson
Heydy Ramirez (MS), Raytheon

Honors and Professional Affiliations

NSF National Young Investigator Award, 1993-1999
Best Teacher Award, School of Materials Engineering, Purdue University, 1993
General Motors Faculty Fellowship, Purdue University, 1992-1995
Alexander von Humboldt Fellowship, Max-Planck-Institut, Stuttgart, Germany, 1990-1991
Electron Microscopy Society of America Presidential Student Award, 1989
University of Michigan Regents Fellowship, 1985
Iron and Steel Society of AIME Scholar, 1983-1984
ASM (1982-); TMS-AIME (1982-); MRS (1987-); AcerS (1987-)